ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

PROJECT NO. 6 - VISION IN TANKS

Partial Report On

Sub-Project No. 6-1, Determination of the Visual Requirements for Various Tasks in Armored Vehicles (Spotting, Gunnery, Driving, etc.)

THE ADVANTAGES OF USING BINOCULARS FOR NIGHT SEEING

Project No. 6-1

24 March 1945

ARMORED MEDICAL RESEARCH LABORATORY
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1. PROJECT: No. 6 - Vision in Tanks. Partial Report on Sub-Project No. 6-1, Determination of the Visual Requirements for Various Tasks in Armored Vehicles (Spotting, Gunnery, Driving, etc.).

a. Authority: Letter, Commanding General, Headquarters Armored Force, Fort Knox, Kentucky, 400.112/6 GNOHD, dated 24 September 1942.

b. Purpose: To determine the advantage of using binoculars for night seeing.

2. DISCUSSION:

It is a common, but fallacious belief, that ordinary binoculars are useful only for daytime seeing and that a mysterious kind of "night glass" is required for night seeing. Consequently, issue binoculars are seldom carried or used during night operations. Actually, the advantage of the present standard issue binoculars for night seeing is immediately apparent to anyone using them at night and while even better seeing can be obtained with binoculars of higher power and larger exit pupil, the benefit to be derived from GI binoculars is striking. Lights and objects which cannot be seen with the unaided eye are seen and objects which can be seen but whose form cannot be distinguished with the unaided eye are easily recognized.

In order to appraise the improvement in vision quantitatively and determine the relative contributions of objective lens diameter and power to this improvement, experiments were carried out using the (M3) 6 x 30/GI binocular (six power, 30 mm objective lens diameter) Navy 7 x 50 binocular and the 10 x 45 B.C. scope. Results are shown graphically in Figure 1. Use of the binoculars by troops on night operation problems confirmed the practical advantages indicated by the experiments.

3. CONCLUSIONS:

a. Use of the present issue (M3) 6 x 30 binoculars makes it possible to recognize a target at night at approximately 3.5 times the distance at which the same target can be recognized with the unaided eye under the same starlight conditions.

b. The 7 x 50 Navy binoculars make it possible to recognize a target

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at night at approximately 4.75 times the distance at which the same target can be recognized with the unaided eye under the same starlight conditions.

c. The greater the magnification of the binoculars and the greater light gathering, the farther objects can be seen and recognized at night.

d. Night lookouts, reconnoiterers, sentries, night combat officers and key men in all night operations should be supplied with binoculars for night use. They should be advised of the advantages to be gained from binoculars and instructed in their proper use.

e. The fundamentals of efficient night seeing for the unaided eye (e.g., dark-adaptation, off center vision, and scanning) also apply when using binoculars.

f. The above conclusions also apply to monocular sighting equipment; hence the need for and recent trend toward sights incorporating greater power and larger objectives. Recognizing the importance of these factors for sighting at low illumination, such sights as the T-8, M-10, M-76, etc., were developed and are now in production for tanks. These instruments give to the tank gunner seeing ability at low light levels equivalent to that of the tank commander using binoculars with comparable characteristics. Such sight characteristics are required for all guns employed for direct laying at low illumination levels. In view of the results herein reported, little imagination is required to appraise the relative night hitting ability of tanks with sights of proper characteristics as opposed to tanks with formerly existing sighting equipment.

4. RECOMMENDATIONS:

a. That information relative to the advantages of binoculars for night use be disseminated through all proper Army channels and inter-Army publicity.

b. That the issue of binoculars to all branches be reconsidered and supplementary issue made where necessary to insure adequate supply for use in night viewing.

c. That instructions in the use of binoculars become a part of all night training.

d. That instructions be issued with each pair of binoculars on the care and use of binoculars for both day and night viewing.

e. That lens cloths or lens tissue be included in weatherproof container in binocular case.

NOTE: The recommendations as set forth in this project have been concurred in by Col. Fred W. Makinney, Chief of Staff, Armored Center.

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#1 - Appendix
#2 - Figs. 1 thru 5

APPENDIX

As stated in the discussion, it is not generally appreciated that ordinary binoculars are useful at night. This point was established by interviewing men with broad combat experience, all of whom, after using binoculars on simulated night operations, were astonished at their practical usefulness for all types of night operations. This clearly indicates that there is a real need for: (1) disseminating information throughout the Army on the advantages of binoculars for all night operations and (2) furnishing more binoculars to combat troops. For night reconnaissance, night sentry to prevent infiltration, night lookouts, night fire control, etc., they will prove an indispensable aid.

A study was made of the advantage to be gained with binoculars of differing power and lens diameters to determine the influence of these factors on optical design. The curves representing the advantage, expressed as multiples of naked eye threshold form recognition distance for various lens diameters, are shown in Figure 1. Figure 2 expresses the advantage for one observer in terms of form recognition distance. The studies, from which these curves were obtained, were carried out on moonless nights in the field away from all disturbing artificial light. The starlight illumination was approximately 15×10^{-5} foot candles. The target was a white circle 44 inches in diameter with a $15\frac{1}{2}$ inch black Landolt ring 3 inches wide with a $3\frac{1}{2}$ inch break. Form recognition threshold was determined as the maximum distance at which the subject was able to determine correctly 3 out of 4 or 6 out of 8 orientations of the Landolt ring with random orientation of the ring in any of four positions: up, down, right or left. All subjects were dark-adapted prior to test.

Data obtained from six observers of average ability and limited training are shown in Figure 1. Here the maximum distance for form recognition using binoculars is plotted, as a multiple of that for the unaided eye, against the objective lens diameter. More complete data obtained from a single skilled observer are shown in Figure 2.

Information obtained from these experiments furnishes a basis for the choice of optical properties of instruments best suited to night operations. Selecting those values obtained for different magnifications yielding the same exit pupil of 4.5 mm, Figure 3 is obtained. Within the accuracy of the experiment, a simple linear relation of the distance factor in terms of the naked eye distance to magnification is observed. This is to be expected from theory and may be safely used for deriving other relationships.

On the basis of this linear dependence upon power, all the data can be used to compute the values for a common magnification of ten times. We thus obtain Figure 4 showing the dependence of distance factor on exit pupil. Here all the data derived from different powers varying from 6x to 10x yield a single curve well within experimental error.

Thus, magnification and exit pupil may be regarded as two independent factors contributing to the effectiveness of binoculars for night operations.

APPENDIX

The advantage gained varies in direct proportion to the power or magnification. Advantage gained from enlarging the exit pupil increases sharply at first (in the range of 2 to 3 mm), then more gradually until one reaches a range of rapidly diminishing return (7 to 8 mm).*

From the fundamental curves shown in Figures 3 and 4, we may derive a family of curves relating objective lens diameter and power to distance factor (power as parameter). See Figure 5. From these curves, it will be noted that the greatest advantage is gained from a given objective diameter when the power is such as to give a 3 mm exit pupil; i.e., the point of tangency of each curve on the line is:

$$\frac{\text{Objective diameter}}{\text{power}} = 3 \text{ (approx.)}$$

Greater power and smaller exit pupil may even prove a disadvantage.

Of course, other considerations, such as loss of field or difficulties due to image motion, may limit the advantages of increased power. It is then advantageous to increase the exit pupil to the practical limit. Such is the case in most instruments, about 7 mm being regarded as the practical limit.

The most important factor not considered in these experiments is the size of field. Qualitative observations indicate that a wide field is definitely advantageous. It is especially important in recognizing large objects (tanks, etc.). The present findings are based upon observations on a relatively small object and hence do not indicate the influence of field to any great extent.

With a large exit pupil (7.2 mm), the factor of advantage in distance is found to be 70% of the power, (e.g., 7x binocular increases the recognition distance 4.75 times). A contributing factor to the efficiency of binoculars is the percentage of light transmission. The binoculars employed in these tests were not coated and all gave a transmission of about 50%. Half wave coating, which improves transmission, would undoubtedly increase the factor of advantage to a greater proportion of the magnification.

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* The form of this curve (Figure 4) is not in accord with simple theory, though the maximum approached is in agreement. A greater advantage in the middle range of exit pupil is observed. This implies an effect similar to the Stiles Crawford effect. Since the illumination level is such that only rod vision can be operative, this is unexpected.

FIG. 1

FORM RECOGNITION DISTANCE EXPRESSED AS MULTIPLE OF NAKED EYE THRESHOLD DISTANCE USING BINOCULARS OF 6, 7 & 10 POWER WITH VARIOUS LENS DIAMETERS

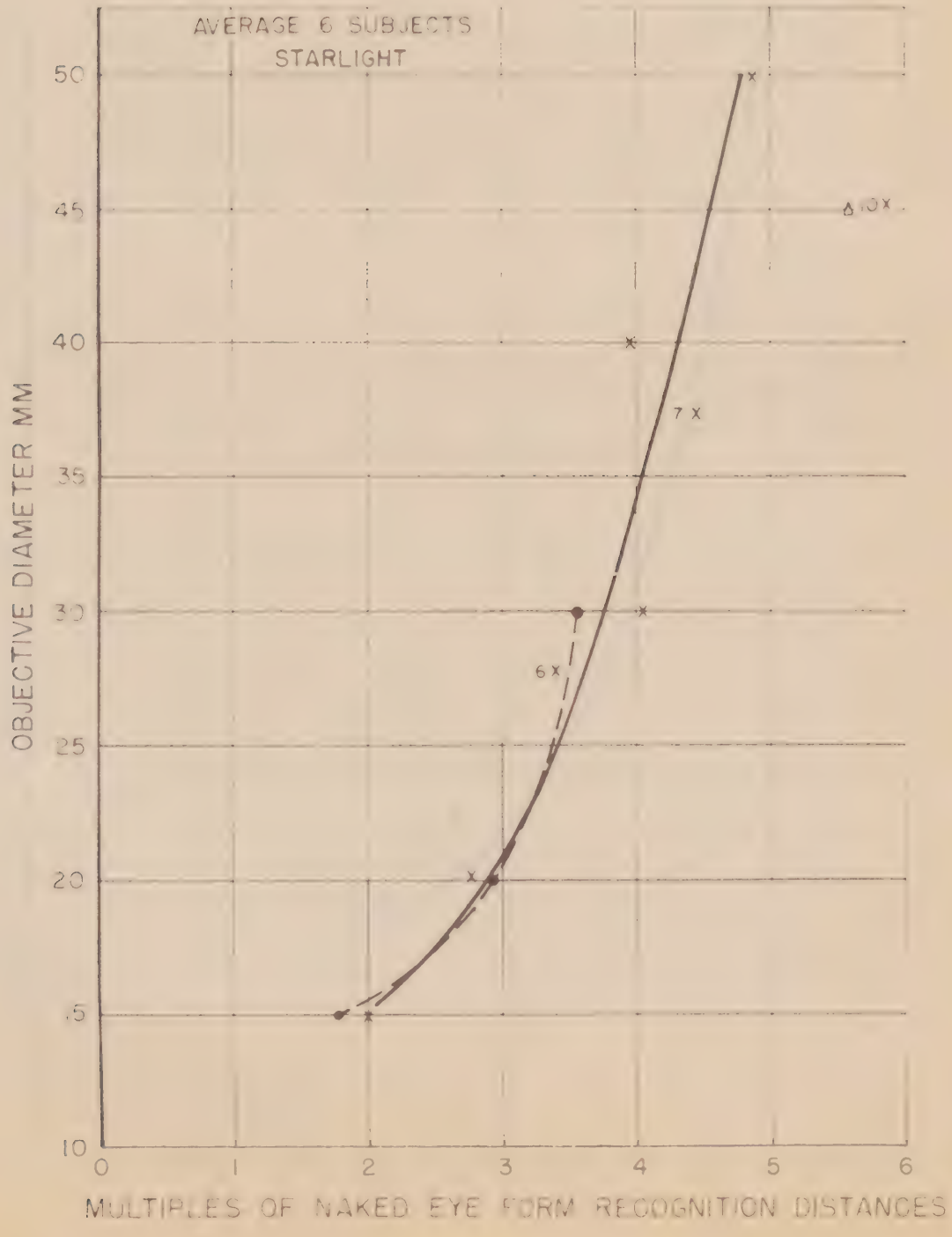


FIG 1

FIG. 2

FORM RECOGNITION DISTANCE USING 6X, 7X AND 10X BINOCULARS WITH VARIOUS LENS DIAMETERS (TRAINED OBSERVER)

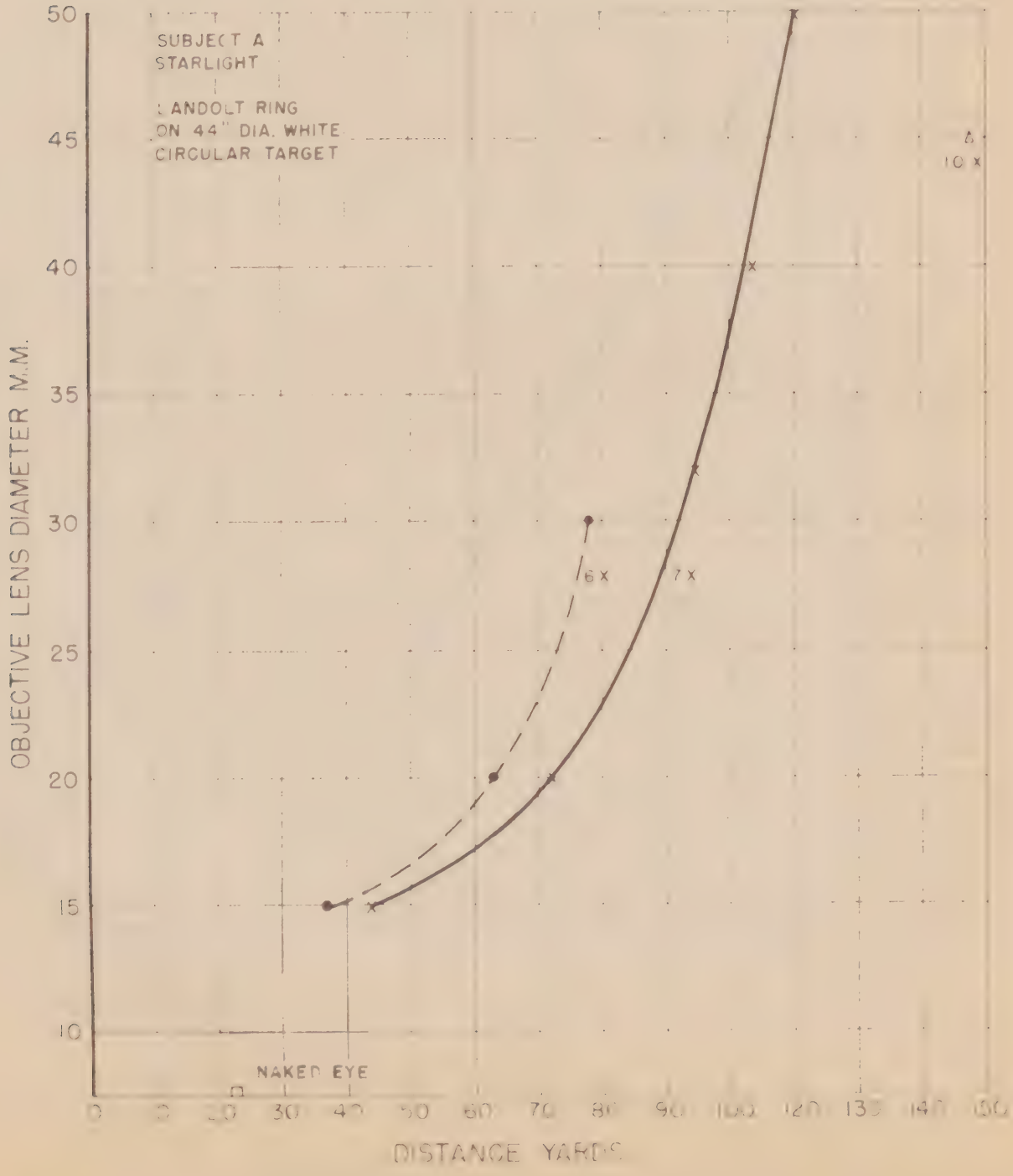


FIG. 2

FIG. 3

ADVANTAGE DEPENDANCE ON POWER

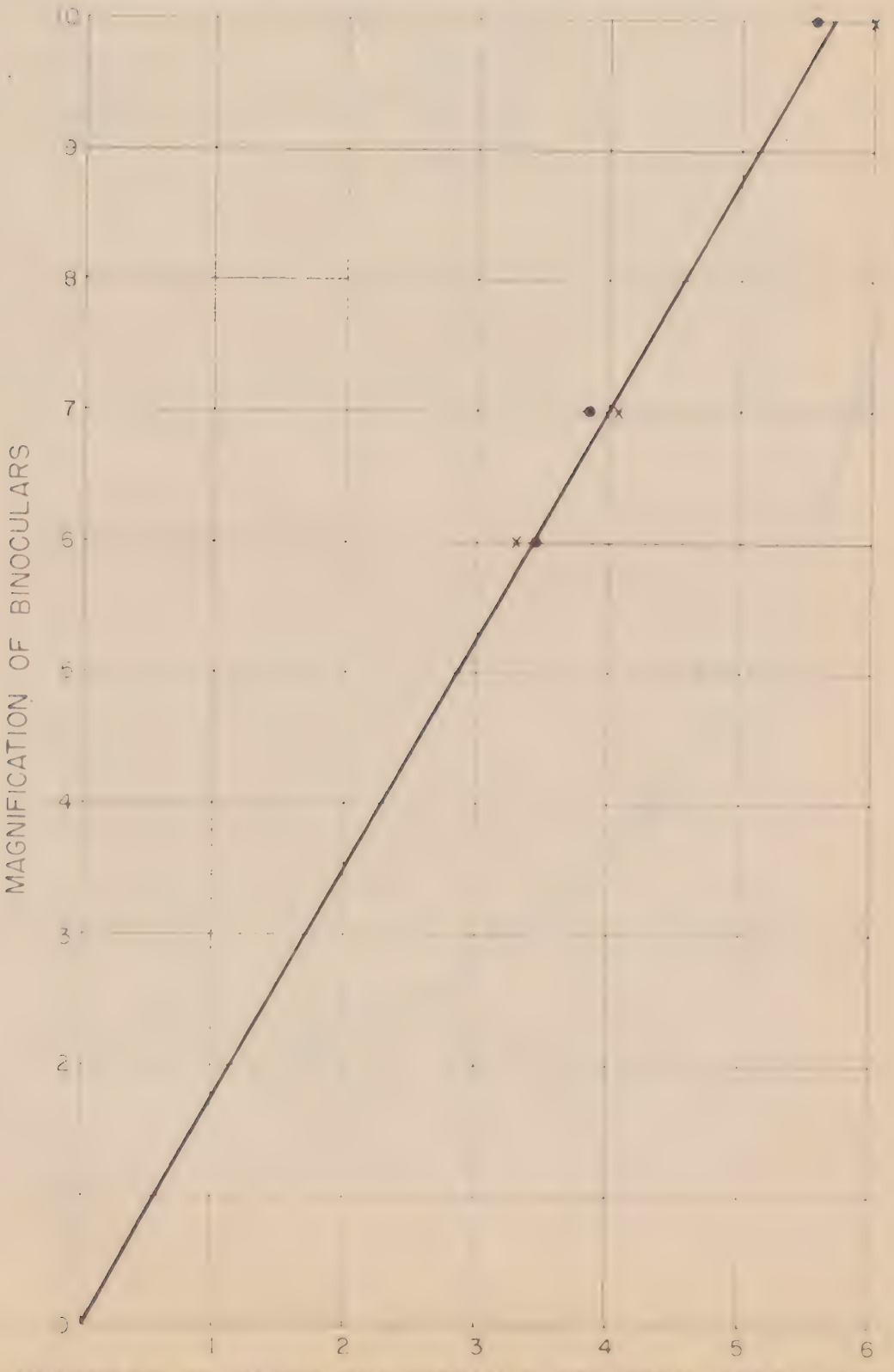


FIG. 3

FIG. 4

ADVANTAGE DEPENDANCE ON EXIT PUPIL

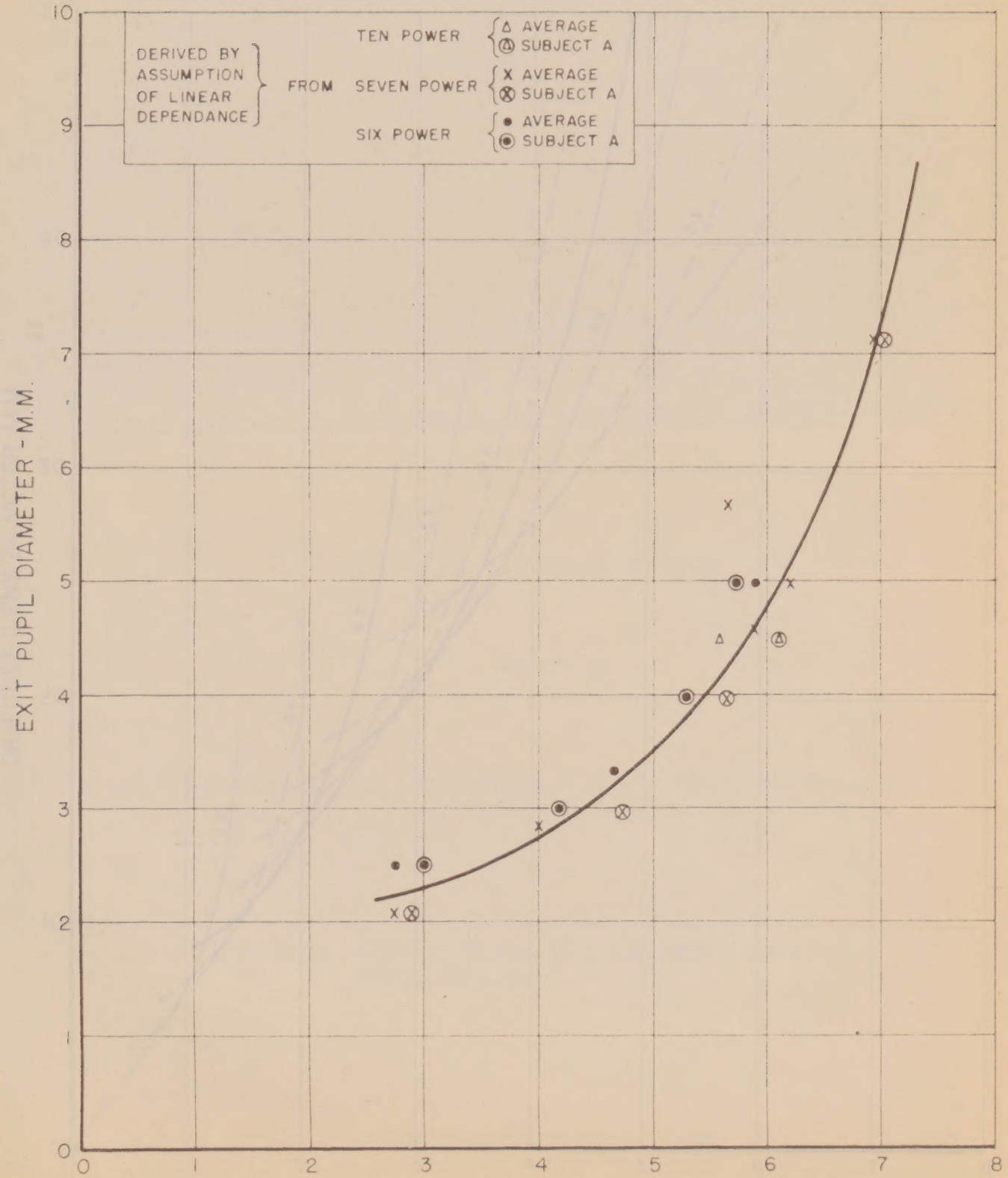


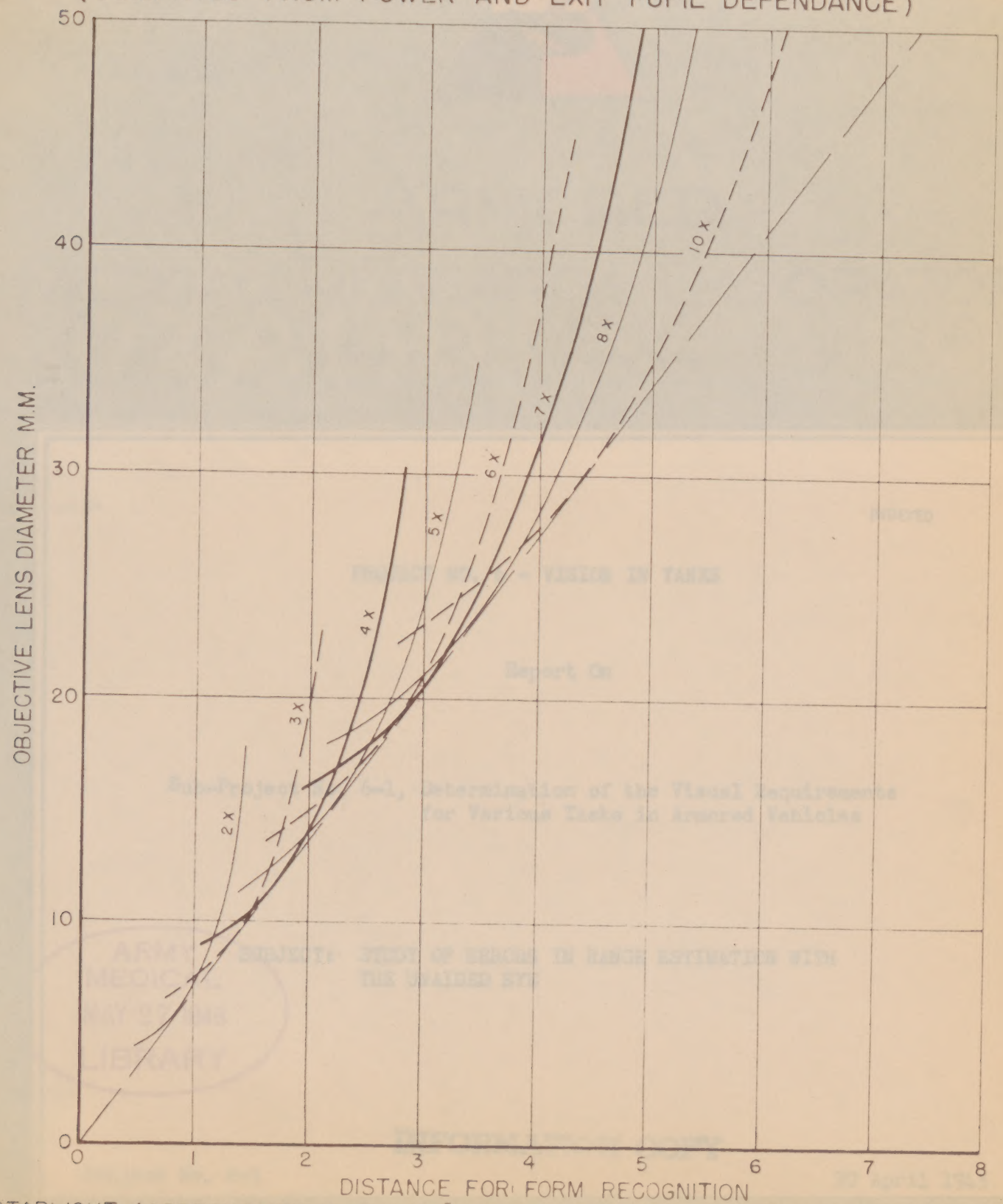
FIG. 4

Incl. #2

FIG. 5

RELATION OF FORM RECOGNITION DISTANCE TO OBJECTIVE LENS DIAMETER FOR VARIOUS MAGNIFICATIONS

(COMPUTED FROM POWER AND EXIT PUPIL DEPENDANCE)



STARLIGHT (APPROXIMATELY 15 X 10^{-5} FT. LAMBERTS) - LANDOLT RING (3.5" BREAK)

FIG. 5